Storage dynamics of fallen trees in a mixed broadleaved and Korean pine forest

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Abstract: A study of the storage dynamics in the mixed broadleaved and Korean pine forests was carried out in the Changbai Mountains, Jilin Province, P. R. China. The modifying law of fallen trees was the storage dynamics of the existing fallen trees and the annual input in the mixed broadleaved and Korean pine forest. The current storage of fallen trees was 16.25 $t\cdot hm^{-2}$ in the initially, but after 100 years, 85% of the storage in dry weight was decomposed, and little material was left after 300 years. The average annual input of fallen trees was 0.6 $t\cdot hm^{-2}$and it increased with time to 31.0 $t\cdot hm^{-2}$after 200 years, which was maintained until the climax community ended. The total storage of fallen trees increased in the early stage. The decomposition of fallen trees eventually reached equilibrium with storage being identical with the annual input of fallen trees.

Key words: Broadleaved/Korean pine forest, Storage, Dynamics, Fallen trees, Changbai Mountains.

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Introduction

Fallen trees are important components of forest ecosystems, a nutrient pool for forest animals and microbes, and also an important part of the energy and material flow in forests (Harmon *et al.* 1986; Franklin *et al.* 1987). Forest ecologists thus attach importance to the study on fallen trees.

A series of studies of fallen trees has been conducted in the Changbai Mountain Forest ecosystem, since 80s, to investigate the cause of death and existing storage biomass of fallen trees, decomposition dynamics of coarse woody debris and the decomposition processes of snags in mixed forests of broadleaved species but dominated by Korean pine (Xu *et al.* 1998; Heal *et al.* 1983; Hao *et al.* 1989). The research on storage dynamics of fallen trees was reported just recently because of complexity and volume of the research (Xu *et al.* 1998; Dai *et al.* 1999).

Study area and methods

Natural conditions

The mixed broadleaved and Korean pine forest in the Changbai Mountains is common between the altitudes of 500 m and 1000 m where there is a substrate of basalt. The soil is the Mountain dark brown forest soil and originates from the pozzolana. The dominant tree species are *Pinus koraiensis, Tilia amurensis, Tilia mandshurica, Fraxinus mondshires* and *Acer mono.* Calculating by growing stock, we know that the *Pinus koraiensis* usually takes up 60%, sometime up to 70%~80% and the left is broad-leaved trees such as *Tilia.* Growing stock is 350~400 $m^3\cdot hm^{-2}$ for the mixed broadleaved and Korean pine forest. There are two plots with trees at age of 350~400 in the Dayangcha in the Changbai Mountain Nature Reserve. In the plots there exists large amount of dead storage, with a volume of 40~50 $m^3\cdot hm^{-2}$. For rotten state, 75% of the fallen trees are in II-class and III-class, 15% of them is in I-class, and less is in V-class (Chen *et al.* 1992; Wang *et al.* 1982).

Study methods

Sampling fallen wood:

Selection of cutting stands with similar habitat and different cutting ages was carried out in Heping Forest Farm and Huangsongpu Forest Farm. Some fallen trees with no heartwood rot were reserved and considered to be cut the same year. Hence, the decomposition age of fallen trees was determined by the cutting time of the stands. Thirty-six fallen trees of *Pinus Koraiensis* and 24 fallen trees of *Tilia amurensis* were collected. The fallen trees were cut to disks with 5 cm in thickness. The seriously rotten wood was collected with an aluminum box of known volume. Density and nutrient elements of those samples were analyzed in the lab. Constant weight was adopted to determine the density of wood. The volume for each sample was measured by using volumenometer, after then, samples were cut to l bits of wood and put into the oven for drying at a temperature of

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70-80℃.

Annual input of fallen trees:

Enumeration survey was conducted on four permanent plots, which were established in 1979, of the mixed broad-leaved and Korean pine forest. The marked dead trees was checked and recorded by name, diameter at breast height, the length of fallen parts (h), and the total length of dead trees (H). The biomass of dead trees was calculated by regression equation of trunk biomass to obtain the annual death weight of timber(W), then according to the equation, $W_1 = (h/H) \times W$, we reckon the annual input fallen trees (Xu *et al.* 1998; Chen *et al.* 1991, 1992).

Results and analysis

Formation of fallen trees

Forest experiences the processes of generation, growing, development, mature, and death. However, the death of forest does not start from the development or the mature stage, and self-thinning accompanies the whole development process in fact. Because of the longevity differentiation between trees in forest, even in the forest with same life span or form in the mature stage, not all trees come to death at the same time. The occurrence of self-thinning results not only from genetic factor of trees, but also from disease and pest, human disturbance, animal harm, competition between trees, and natural harms.

Owing to the feeble capability of anti-adversity, young tree is likely dying out. The calculating result, by the ratio of the fallen tree numbers of different diameter classes to total number of fallen trees, showed that the fallen trees of small diameter took a rather large proportion in the mixed broadleaved and Korean pine forest. As shown in Fig. 1, the ratio of fallen trees decreased obviously with increasing of diameter. Most of the fallen trees are in range of 10-40 cm in diameter, corresponding to the standing trees. There are fallen trees with varied ages and different diameters in a mixed broadleaved and Korean pine forest, and most of them are about 30 cm in diameter.

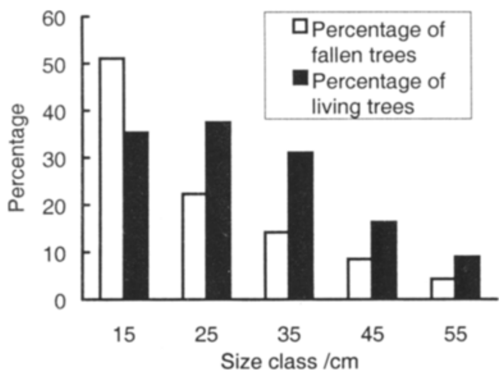

Fig.1 Percentage of size-class partition of fallen wood in the mixed broad-leaved and Korean pine forest

Forest can ceaselessly produce fallen trees. The storage dynamics of fallen trees includes the existing fallen trees and annual input of fallen trees. The existing fallen trees imply the current total accumulation, or dry weight, of fallen trees including trees, large branch, and trunk that died in different ages. These fallen trees are in different decomposition and rotten classes. The annual input of fallen trees means the total accumulation, or dry weight, of the fallen trees newly added in every year after investigation. Thus, the storage dynamics of fallen trees should comprise the dynamic model of existing fallen trees, the model of annual input, and integrated model as well.

Dynamic model of storage decomposition of existing fallen trees

If the biomass, or dry weight, of the existing fallen trees and its decomposition rate to a certain degrees are known, the storage dynamic model of existing fallen trees can be written as:

$$W = \sum_{i=1}^{m} G_i P_i^n \tag{1}$$

Supposed the storage of existing fallen trees is composed of various tree species, then the model is written as:

$$W = \sum_{j=1}^{N} \sum_{i=1}^{m} G_{ji} P_{ji}^n \tag{2}$$

where: W represents the dynamic storage of existing fallen trees; G is biomass, or dry weight, of existing fallen trees; P is decomposition rate to a certain state of fallen trees; m number of fallen trees; N is the species of fallen trees; j, I is serial number of tree species and number of fallen trees, respectively. j=1, 2, 3..., n; i=1, 2, 3..., m; n is the decomposition years.

Dynamic model of annual input

supposed decomposition dynamics of annual input of fallen trees is T, $T_{1a} = H_1 P_i^n$, $T_{2a} = H_2 P_i^n$, ...$T_n = H_m P_i^n$, then,

$$\begin{aligned} T &= \sum_{i=1}^{m} H_i \left(P_i^n + P_i^{n-1} + \ldots\ldots P_i^1\right) \\ &= \sum_{i=1}^{m} H_i \frac{1 - P_i^n}{P_i^{-1} - 1} \end{aligned} \tag{3}$$

Where: H is the annual input of fallen trees; P is decomposition rate to a certain rotten state; m is number of fallen trees; i is the serial number of fallen trees number, i=1,2,m; n is the decomposition years.

As a mixed broadleaved and Korean pine forest is composed of multiple tree species and the fallen trees also include a number of trees species, the equation (3) can be changed to the following

$$T=\sum_{j=1}^{N}\sum_{i=1}^{m}H_{ji}\frac{1-P_{ji}^{n}}{P_{ji}^{-1}-1} \tag{4}$$

Where: j is serial number of tree species, j=1, 2... n; other symbol is the same with the previous formula.

Storage dynamic model of fallen trees

Combine equations (2) and (4), we can obtain the he storage dynamic model of fallen trees for the mixed broad-leaved and Korean pine forest:

$$Z=W+T$$
$$=\sum_{j=1}^{N}\sum_{i=1}^{m}G_{ji}P_{ji}^{n}+\sum_{j=1}^{N}\sum_{i=1}^{m}H_{ji}\frac{1-P_{ji}^{n}}{P_{ji}^{-1}-1} \tag{5}$$

Storage dynamics of fallen trees

Existing fallen trees

The number, dry weight, and decomposition rate of the existing fallen trees are listed in Table 1. As shown in Fig. 2, most of the fallen trees had decomposed over after 100 year. The fallen wood of *Tilia amurensis* needs 430 years to decompose over. *Pinus koraiensis* has low decomposition rate and about 3% of biomass (dry weight) is still remained after 910 years. The decomposed amount (dry weight) of fallen wood for *Pinus Koraiensis, Tilia amurensis,* and other broad-leaved trees within 50 years is 72.2%, 81.2% and 86.2%, respectively (Fig. 3). After 100 years, for *Pinus koraiensis,* 7.5% of fallen wood biomass still remains, while for *Tilia amurensis* and other broad-leaved trees only 2-3% of fallen wood biomass remains. Up to 300 years, the remained amount of fallen wood for *Pinus koraiensis*, *Tilia amurensis*, other trees, and total storage is 0.3%, 0.01%, 0.007%, and 0.1% of original biomass, respectively.

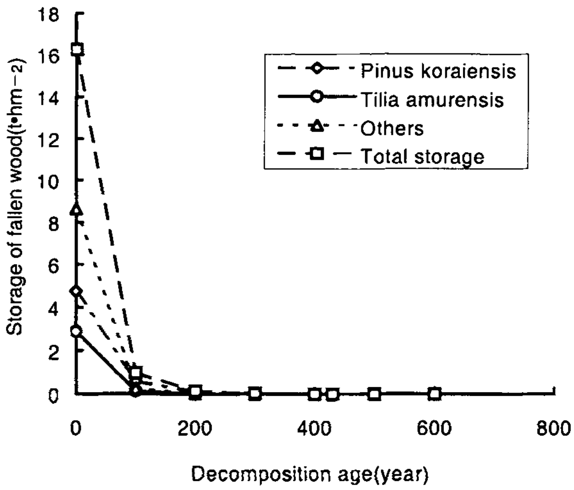

Fig.2 Dynamics of existing fallen wood storage in the mixed broad-leaved and Korean pine forest

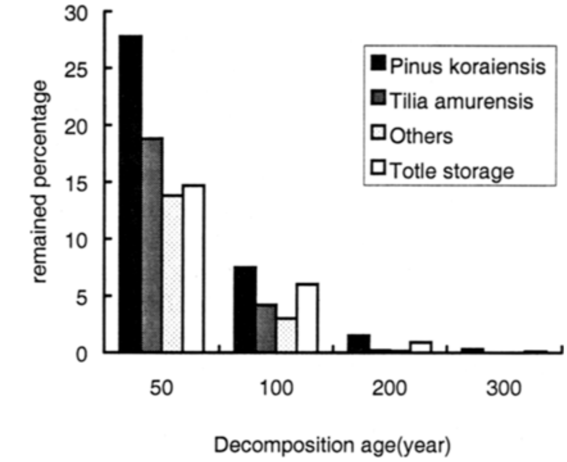

Fig. 3 The remained dry weight (percentage) of fallen wood at different decomposition age in the mixed broad-leaved and Korean pine forest

Table 1 Existing storage and decomposition rate of fallen wood in the mixed broad-leaved and Korean pine forest

Species		Number	Biomass ($t\cdot hm^{-2}$)	Resolving power (%)
		1	0.71	0.98646
		3	0.453	0.98448
Pinus		5	0.252	0.98323
koraiensis		7	0.126	0.97558
		17	0.032	0.97532
	Sum	33	4.75	
		1	0.87	0.97110
		1	0.58	0.97034
Tilia		1	0.35	0.97019
amurensis		3	0.24	0.97003
		6	0.0583	0.96788
	Sum	12	2.87	
		2	0.765	0.97110
		4	0.51	0.97034
Other		7	0.31	0.97019
species		11	0.153	0.97003
		25	0.05	0.96788
	sum	49	8.63	
Total		94	16.25	

Storage dynamics of annual input of fallen trees

Different sites of the mixed broad-leaved and Korean pine forest have different annual input of fallen trees (Table 2), and the average annual input rate is about 0.65 $t\cdot hm^{-2}$, which includes 60% of Korean pine and 40% of broad-leaved tree. According to Equation (4), the decomposition dynamics of annual input of fallen trees is:

$$T=0.39\frac{1-0.9824^{n}}{0.9824^{-1}-1}+026\frac{1-0.97457^{N}}{0.97457^{-1}-1} \tag{6}$$

Table 2 Mortality survey of different sites

Forest type	Survey site	Elevation (m)	Area (hm^2)	Reexamine time (year)	Dead trees	Mortality every year (hm^{-2}) Number	Biomass (t)
Mixed broad-leaved and Korean pine forest	No.1	740	1	9	9	1.0	0.66
	Cha di	740	1	9	3	0.3	0.46
	Xiao qiao	740	1	9	4	0.4	0.15
	Da yangcha	740	1	9	19	2.1	1.23

The total storage of fallen trees is less in the initial decomposition stage, after then it increases gradually and tends to be stable at 31t per hectare after 150 years till to the end of climax (Fig. 4).

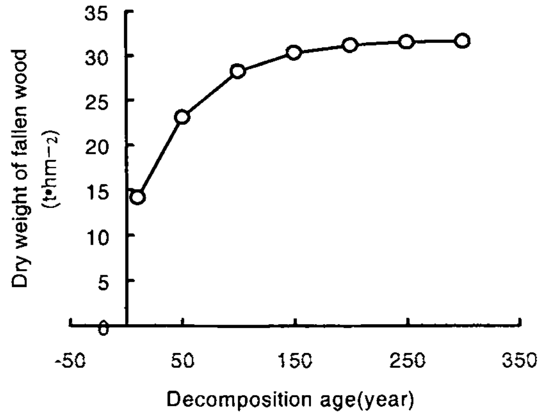

Fig. 4 Storage dynamics of fallen wood in the mixed broad-leaved and Korean pine forest

The increase in total storage of fallen trees in early stage is mainly contributed by the annual input of fallen trees. After the existing fallen trees decomposed, the total storage was derived completely from annual input.

Mixed broadleaved and Korean pine forests have the similar ecological environment and the resemble dynamics of fallen trees. The storage of the existing fallen trees follows the common principles and decreases with the lapse of time, and most timbers have decomposed within the 100 years.

Conclusions

The storage of fallen trees in a mixed broadleaved and Korean pine forest is quite large. By dry weight, it amounts to 10 m^3 or 10 t per hectare. The decomposition follows a common principle in terms of trends of fallen tree storage in mixed broadleaved and Korean pine forest. For example, the existing storage of fallen trees decreased with the lapse of time, and 86% of the storage had decomposed after 100 years. Because the annual input is higher than the annual decomposition rate in the initial stage, the storage increases in this stage, but after 150 years, it tends to be stable at $31t\cdot hm^{-2}$.

The storage dynamics of fallen trees rest with not only existing fallen trees and annual input, but also the composition of fallen trees as well as diameter class. Uneasily decomposed tree, such as Korean pine, accounts for a high ration of the storage. The decomposition speed of broad-leaved trees is faster than that of Korean pine.

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